*American National Standard*
*for Information Technology—*

# *Geographic Information Framework – Draft Data Content Standards For Transportation Networks: Transit*

American National Standard
for Information Technology

# Geographic Information Framework Draft Data Content Standards For Transportation Networks: Transit

(Part XXX)

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Note to Commenters: Although this working draft is presented as a stand-alone standard, it is intended to become part of a single, harmonized NSDI Framework Data Content Standard. In all, five transportation subthemes and seven Framework themes will be harmonized into one standard for presentation to the InterNational Committee on Information Technology Standards, Geographic Information Systems[1] . Structural and formatting changes are likely to occur to this and other working drafts during the harmonization process. While editorial comments are very welcome on this and any working draft, standards' development would benefit most, at this time, from comments on scientific and technical issues. The single, harmonized draft will also be made available for public review and comment.

To comment on working drafts, please use the Microsoft Excel comment spreadsheet located at http://www.geo-one-stop.gov/Standards/index.html. Only comments received in this format will be considered. You can email comments to GeospatialComments@geo-one-stop.gov., or mail them to the following address:

Geospatial Comments
The MNG Center at SRA International
2425 Wilson Blvd.
Suite 400
Arlington, VA 22201

[1] See the diagram, "Nested Relationship of NSDI Framework Data Content Standard Harmonization" at the end of this *document.*

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## *Foreword*

The primary purpose of the standard is to support the exchange of transportation data related to transit systems. This standard also seeks to establish a common baseline for the content of transit databases for public agencies and private enterprises. It seeks to decrease the costs of acquiring and exchanging transit data for local, tribal, state, federal, and North American users and creators of transit data. Benefits of adopting the standard also include the long-term improvement of the geospatial transportation base data, improved integration of safety, emergency response, and enforcement data, and streamlined maintenance procedures.

This standard has been developed to fulfill one of the objectives of the NSDI, i.e., to create common geographic base data for seven critical data themes. These core themes are considered Framework data, reflecting their critical importance as geographic infrastructure. The Geospatial One Stop initiative is an e-government initiative of the federal government designed to expedite the creation of the seven Framework layers. This standard has been developed in response to the One Stop initiative to realize the goals and objectives of the NSDI.

Suggestions for improvements of this standard will be welcome. They should be sent to

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This standard was processed and approved for submittal to ANSI by the Accredited Standards Committee – INCITS/L1. Committee approval of this Standard does not necessarily imply that all committee members voted for its approval.

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**American National Standard for Information Technology**
**Geographic Information Framework**
**Data Content Standards**
**(ANSI X.X.X2003)**

# 1 Scope of this Standard

This standard defines components of public transportation (transit) systems, which is one of at least five modes that compose the transportation theme of the Geospatial One-Stop data framework. The primary purpose of this standard is to support the exchange of spatial and temporal data related to public transportation. The emphasis in developing this standard has been on supporting data exchange on a regional level to support itinerary planning, infrastructure inventories, and re-routing applications.

As a transportation mode, transit differs substantially from other modes such as rail and road in that core operational features of the transit system consist of spatial and temporal elements that rest upon the transportation infrastructure. The transit system described in this standard is made up of linear features (such as roads) the route or pattern features that rest upon linear features, system stop locations, and other features associated with the operation of transit systems.

The classes, features, and characteristics included in this standard were developed as part of a comprehensive review of several use cases that have been documented here. Although these use cases addressed the operational requirements of a broad selection of Transit business scenarios, they did not provide sufficient input to design an all-inclusive Transit model. Additional use cases will be required to identify the universe of classes, features, and characteristics necessary to fully describe the Transit geographic base data theme.

The standard can be implemented using a variety of software packages and is designed to accommodate data encoded without geometry as well as to support the exchange of data encoded in a variety of geographic information systems. It is designed to be able to depict the complete transit system at all levels of service and all functional classes that may be defined by a data-providing agency.

The transit standard applies to National Spatial Data Infrastructure (NSDI) Framework transportation data produced or disseminated by or for the federal government. According to Executive Order 12906, Coordinating Geographic Data Acquisition and Access: the National Spatial Data Infrastructure (Clinton, 1994, Sec. 4., Data Standards Activities), federal agencies collecting or producing geospatial data, either directly or indirectly (e.g., through grants, partnerships, or contracts with other entities), shall ensure, prior to obligating funds for such activities, that data will be collected in a manner that meets all relevant standards adopted through the Federal Geographic Data Committee (FGDC) process.

This standard is part of a set of transportation standards that are to be integrated into a comprehensive standard to support five primary modes of transportation systems: roads, rail, transit, air, and water. The developers of the current transit standard recognize the need to extend the model being developed in the rail mode for the purposes of transit modeling. Rail transit components will be incorporated in the second draft of this standard. Recommendations will be incorporated into this standard where applicable.

## 2 Normative References

The following standards contain provisions, which through reference in this text constitute provisions of this American National Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this American National Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below.


[1] Federal Register, Vol. 59, No. 71, pp. 17671-17674, *Executive Order 12906*, April 13, 1994.

[2] ISO/TR 14825 GDF, Geographic Data Files, Version 4.0

[3] ANSI NCITS 320-1998, *Spatial Data Transfer Standard (SDTS)*.

[4] FGDC-STD-001-1998, *Content Standard for Digital Geospatial Metadata (version 2.0)*.

[5] FGDC-STD-002.5, *Spatial Data Transfer Standard (SDTS), Part 5: Raster Profile and Extensions*.

[6] FGDC-STD-002.6, *Spatial Data Transfer Standard (SDTS), Part 6: Point Profile*.

[7] FGDC-STD-002.7-2000, *SDTS Part 7: Computer-Aided Design and Drafting (CADD) Profile*.

[8] FGDC-STD-007.1-1998, *Geospatial Positioning Accuracy Standard, Part 1, Reporting Methodology*.

[9] FGDC-STD-007.3-1998, *Geospatial Positioning Accuracy Standard, Part 3, National Standard for Spatial Data Accuracy*.

[10] FGDC-STD-007.4-2002, *Geospatial Positioning Accuracy Standard, Part 4: Architecture, Engineering Construction, and Facilities Management*.

[11] INCITS 353:2001, *Spatial Data Standard for Facilities, Infrastructure, and Environment*.

[12] ISO 19107, Geographic Information—Spatial Schema.

[13] ISO 19109, Geographic Information—Rules for Application Schema.

[14] ISO 19110, Geographic Information—Feature Cataloging Methodology.

[15] ISO 19111, Geographic Information—Spatial Referencing by Coordinates.

[16] ISO 19115, Geographic Information—Metadata.

[17] ISO 19123, Geographic Information—Schema for Coverage Geometry and Functions.

[18] ISO 19133, Geographic Information—Location Based Services Tracking and Navigation.

[19] ANSI, X.X.X2002,Geographic Information Framework—Data Content Standards for Transportation Networks: Roads.

[20] Transit Standards Consortium, Bus Stop Inventory Best Practices and Recommended Procedures, 19 September 2001.

[21] NTCIP 1400:2000 Transit Communications Interface Profile Framework, Version 1.04, Draft NTCIP 1400 Amendment 1, September 2002.

[22] NTCIP 1401:2000 Standard on Common Public Transportation (CPT) Objects, Version 1.02, Draft NTCIP 1401 Amendment 1, September 2002.

[22] NTCIP 1402:2000 Standard on Incident Management (IM) Objects, Version 1.02, Draft NTCIP 1402 Amendment 1, September 2002.

[23] NTCIP 1403:2000 Standard on Passenger Information (PI) Objects, Version 1.02, Draft NTCIP 1403 Amendment 1, September 2002.

[24] NTCIP 1404:2000 Standard on Scheduling/Runcutting (SCH) Objects, Version 1.02, Draft NTCIP 1404 Amendment 1, September 2002.

[25] NTCIP 1405:2000 Standard on Spatial Representation (SP) Objects, Version 1.02, Draft NTCIP 1405 Amendment 1, September 2002.

[26] NTCIP 1406:2001 Standard on On-Board (OB) Objects, Version 1.02, Draft NTCIP 1406 Amendment 1, September 2002.

[27] NTCIP 1407:2001 Standard on Control Center (CC) Objects, Version 1.02, Draft NTCIP 1407 Amendment 1, September 2002.

[28] NTCIP 1408:2001 Fare Collection Business Area Standard, Version 1.02, Draft NTCIP 1408 Amendment 1, September 2002.

[29] ISO 4217, International Currency Codes

[30] ISO 3166, Codes for the Representation of Names of Countries

# 3 Definitions

Definitions applicable to the transit standard are listed here. Other terms may be defined in the Base Transportation Standard.

**Amenity -** The elements of a physical feature, a fixed location, or a transit facility. The amenities of a public transportation stop, for example, may include the shelter, platform announcement panel, and benches. An amenity may be described by one or more characteristics, or attributes, such as the year of construction or its current condition.

**Block** - A block is a sequence of revenue and non-revenue trips to which a transit vehicle may be assigned. A block begins when the vehicle leaves a vehicle base and ends when it returns to a vehicle base.

**Event** - A transit message that is activated at a specified time, location, or both. Not to be confused with linear and point events of the Road model, which may indicate the location of a subordinate transportation element or characteristic.

**Pattern** - A unique, non-branching, ordered sequence of time points, street links, or public transportation stops to be followed by a transit vehicle in scheduled service.

**Piece of Work** - The assignment of an operator to a transit vehicle to execute one or more trips.

**Public Transportation Stop** - An established location where public transport customers may board or alight from a transit vehicle in revenue service.

**Public Transportation Vehicle** - A revenue conveyance in a transit fleet.

**Route** - A collection of patterns in revenue service with a common identifier.

**Time Point** - A location along a pattern where trips are assigned arrival, dwell, or departure time periods.

**Transfer cluster**—A collection of one or more public transportation stops where transfer between routes is accessible and convenient.

**Trip**—A one way scheduled movement of a transit vehicle between starting and ending time points. A revenue-service trip will be an instance of a pattern.

# 4 Symbols (and abbreviations)

Symbols and associated abbreviations applicable to this standard are listed in the Base Transportation Standard.

## 5 The MAT Feature Meta Model

A feature is an abstraction of a real world phenomenon that is of interest to the application. Instances of features that share common characteristics are organized in classes. Classes are object realizations of the Metaclasses defined in the ISO Rules for Application Schemas Standard [13], and instances of the types described in the ISO Feature Catalogs Standard [14]. Road Segments and Intersections are examples of Feature Types.

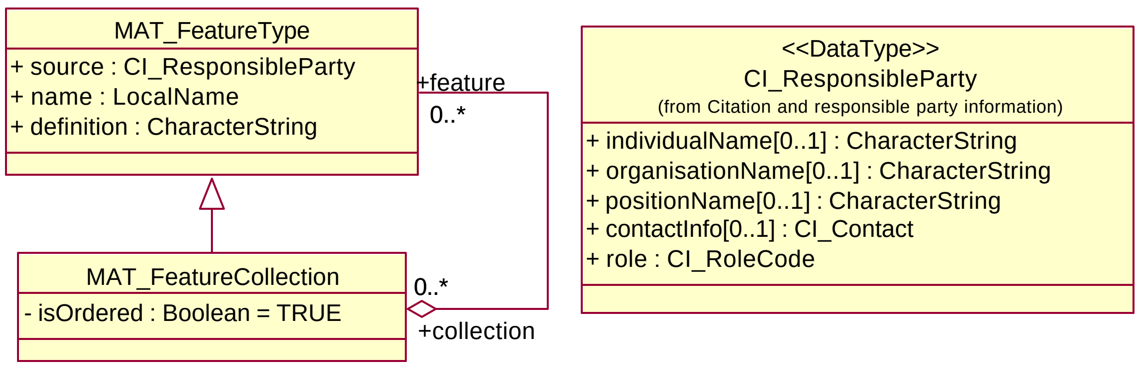


**Figure 1–The MAT Metafeature Model**

Figure 1 shows MAT_FeatureType, which is an object realization of the metaclasses defined in the ISO feature model. Features have names, "LocalName" that are unique within the namespace of the feature collection or the database in which they exist. MAT_Feature has a mandatory attribute called "source".

The source attribute has type CI_ResponsibleParty that is defined in ISO 19115 [16]. It provides standardized method for citing a resource as well as information about the source agency or party responsible (CI_ResponsibleParty) for a resource. The CI_ResponsibleParty data type contains the identity of person(s), and/or position, and/or organization(s) associated with the resource.

MAT_FeatureCollection is a collection of features. Feature collection is an aggregate of zero or more features. Feature collections are also features and therefore can have their own attributes and feature names. Feature collections can be, but not in all cases, defined as ordered lists.

## 6. The Transit System

The Transit system models the geographic locations, interconnectedness, and characteristics of the Transit system. The Transit system includes physical and non-physical components representing primarily the bus mode of travel, though subsequent versions of this standard will include rail transit (e.g. subway, light rail) as well. Four main features are identified in this Transit model. These are transit stops, time points, transit segments, and patterns. Transit segments are the portions of the physical transportation system (i.e. roads) that are defined by the application domain using some business rules that may vary according to the business and technical requirements.

## 6.1 The Context of the Transit System

This version of the Transit Standard is closely related to other models: the MAT feature metamodel, the Linear Reference System, and the Road model. Figure 2 describes the relationship of the Transit model to these other models. The MAT feature metamodel is described above in Section 5. The MAT Road standard [19] is in public review stage and Linear Referencing Systems are discussed in Appendix B.

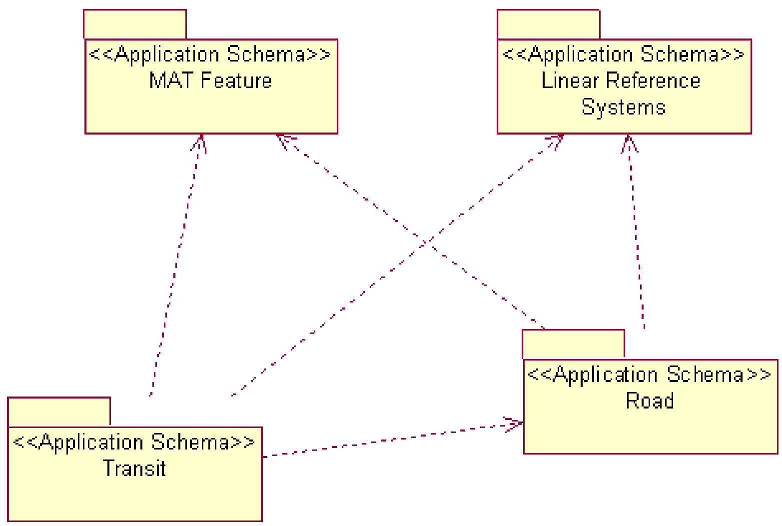


**Figure 2-The Transit Context**

To ensure maximum utility in a variety of contexts, this transit model does not prescribe any specific business rules for the segmentation of the road system. The focus of these standards is to define a way to encode transit points, their routes, and their attributes. The model has three main components:

1. A Segmentation Model inherited from the Road model, that defines segments, collections of segments and their associated geometries and topology.

2. A Transit Stop model, which defines a node of activity where transit passengers transfer to or from public transit vehicles, as well as the scheduling and operational information associated with the transit stops.

3. A Linear Reference Model, which defines a measurement method used apply attributes to segments by locating their endpoints and define their extent.

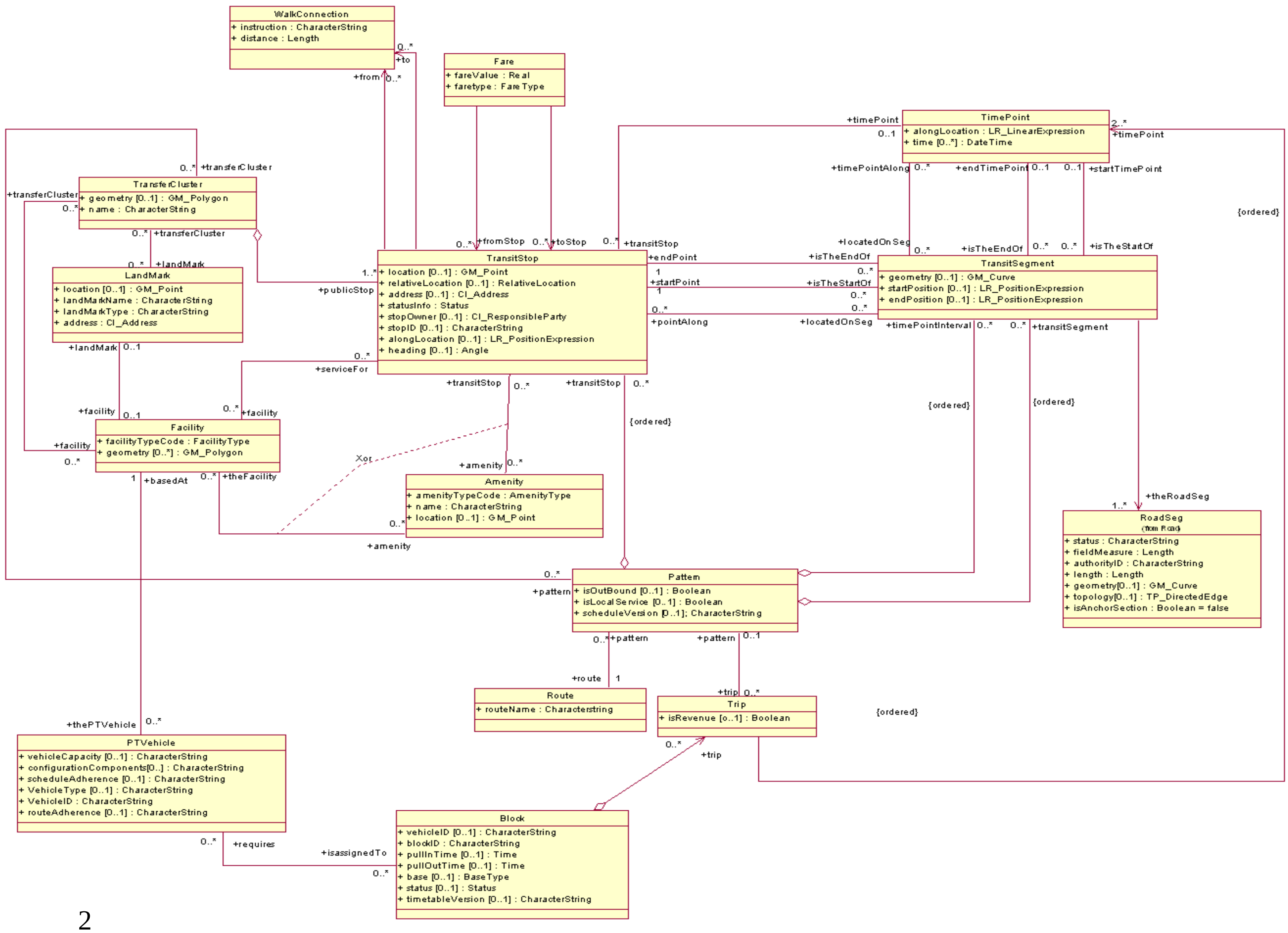


**Figure 3-The Transit System**

### 6.1.1 Semantics

The Transit system has as its central feature the TransitStop. As shown in Figure 3, the Transit system is closely related to TransitSegment, which is derived from RoadSeg. The TransitSegment is also related to TimePoint, Pattern, a WalkConnection, the TransitCluster, Landmark, as well as Facility and Amenity. Also part of the main Transit system are PTVehicle and Block, Route, and Trip. These will be discussed in subsequent sections.

## 6.2 TransitStop

### 6.2.1. Semantics

TransitStop is the central feature of the Transit model. The TransitStop is shown in Figure 3. TransitStop has the geometry of type GM_Point as defined in ISO 19107 [12]. The TransitStop is the starting point for one TransitSegment as well as the end point for a different TransitSegment. Or, the TransitStop could also be a point along a TransitSegment. The TransitStop may also participate as part of a Pattern, an ordered set of TransitStops. The TransitStop may be considered part of a TransferCluster, a group of TransitStops where transit riders can change routes.

## 6.3 TransitSegment

### 6.3.1 Semantics

The TransitSegment is a linear section of the Earth, which is designed for the movement of PTVehicles and is derived from the Road MAT Model. Like RoadSeg, TransitSegment is an extension of the TransportationFeature and is depicted in Figure 3. Consequently, TransitSegment has geometry of type GM_Curve as defined in ISO 19107. TransitSegment also has a topology of type TP_DirectedEdge as defined in ISO 19107. According to ISO 19107, GM_Curve extends GM_OrientableCurve and therefore has direction. The reason TP_DirectedEdge has been introduced is to facilitate the representation of feature topology through its combinatorial structures independent of its geometry. For example in the implementation of this model, a data provider may choose to represent only the geometry of the TransitSegment, which implies a direction inherited from GM_OrientableCurve. Another data provider may choose not to supply feature geometry and only provide the orientation of TransitSegments using their topology attribute.

## 6.4 TimePoint

### 6.4.1 Semantics

The TimePoint is a temporal expression that relates to the TransitSegment or to the TransitStop through the linear referencing as a point expression. Figure 3 shows how TimePoint is related to TransitStop, TransitSegment, and also Trip. TimePoint inherits a geometry type of GM_Point as defined in ISO 19107.

## 6.5 Pattern

### 6.5.1 Semantics

Pattern is an ordered sequence of time points or public transportation stops followed by a transit vehicle in scheduled service and is shown in Figure 3.

## 6.6 Block

### 6.6.1 Semantics

Block is a sequence of trips and is therefore associated with Trip as well as the PTVehicle associated with each Trip. Block is shown in Figure 3 and its composition includes the vehicleID, as well as scheduling information such as pull-in time, pull-out time, the base, and timetable version. There may be zero to many Trips associated with a Block and similarly, there may be zero to many PTVehicles associates with a Block.

## 6.7 PTVehicle

### 6.7.1 Semantics

PTVehicle refers to any public transit vehicle. This object is shown in Figure 3, and contains information about the vehicle including vehicle capacity, vehicle type, as well as routing and scheduling information. The PTVehicle has a one to one relationship with the base Facility.

## 6.8 TransferCluster

### 6.8.1 Semantics

The TransferCluster is closely related to TransitStop since it is comprised of a group of TransitStops where transit passengers can change routes. The TransferCluster has a geometry type of GM_Polygon as defined in ISO 19107 and is shown in Figure 3. The TransferCluster may be associated with zero or many Landmarks, or could be associated with zero or many Facilities. The TransferCluster may also be part of zero or many Patterns.

## 6.9 Landmark

### 6.9.1 Semantics

The Landmark is shown in Figure 3 and has a geometry type of GM_Point as defined in ISO 19107. Landmark is comprised of a name, a type, and an address. There may be zero to many Landmarks associated with a TransferCluster and zero to one associated with a Facility.

## 6.10 Facility

### 6.10.1 Semantics

The Facility has a geometry of GM_Polygon and is also shown in Figure 3. The Facility has a zero to one relationship to Landmark and a zero to many relationship with the TransferCluster. The Facility also has a zero to many relationship to the PTVehicle and also a zero to many relationship to an Amenity. Facility has a zero to many relationship to the TransitStop.

## 6.11 Amenity

### 6.11.1 Semantics

The Amenity is also shown in Figure 3 and has a geometry of GM_Point. An Amenity can be related to either a Facility or to the TransitStop but not simultaneously. The XOR sign, at the associations of Amenity to TransitStop and Amenity to Facility, indicates that an Amenity is either associated with a Facility or with a TransitStop, but not both. Amenity has a zero to many relationship with TransitStop and a zero to many relationship with Facility.

# 7. Code Lists

**Table 1-Code List**

| | Status | Definition |
|---|---|---|
| 1 | ActivationDate | |
| 2 | DeactivationDate | |
| 3 | ModificationDate | |
| 4 | PlacementDate | |
| 5 | DatabaseModificationDate | |
| 6 | StatusTypeCode | |
| 7 | History | |

| | RelativeLocation | Definition |
|---|---|---|
| 8 | OnStreet | |
| 9 | AtStreet | |
| 10 | DistanceFromIntersection | |
| 11 | PlacementRelativeToIntersection | |
| 12 | BusPositionBay | |
| 13 | StreetSide | |
| 14 | IsOffStreet | |

| | RelativeDirection | Definition |
|---|---|---|
| 15 | Nearside | |
| 16 | Farside | |
| 17 | MidBlock | |
| 18 | At | |
| 19 | Between | |
| 20 | FarsideMidBlock | |
| 21 | NearsideMidBlock | |
| 22 | Opposite | |

| | AmenityType | Definition |
|---|---|---|
| 23 | Shelter | |
| 24 | Bench | |
| 25 | Phone | |
| 26 | ScheduleDisplay | |
| 27 | BikeRack | |
| 28 | Restrooms | |
| 29 | InfoFareBooth | |
| 30 | Trashcan | |
| 31 | Other | |

| | FacilityType | Definition |
|---|---|---|
| 32 | Parking | |
| 33 | TransitCenter | |
| 34 | RailStation | |
| 35 | CustomerService | |
| 36 | Garage | |
| 37 | OtherRealProperty | |
| 38 | PowerStation | |
| 39 | RailYard | |
| 40 | Maintenance | |
| 41 | Comfort | |
| 42 | Administration | |

| | FarePolicyType | Definition |
|---|---|---|
| 43 | Flat | |
| 44 | Distance | |
| 45 | Zone | |
| 46 | TimeOfDay | |
| 47 | Transfers | |
| 48 | SpecialRiderClass | |
| 49 | BulkPassDiscount | |

| | Statustype | Definition |
|---|---|---|
| 50 | Active | |
| 51 | Inactive | |
| 52 | Obsolete | |

# Annex A - Trip Itinerary Planning Use Case

In developing the standard, specific transit use cases were utilized to assist in defining the transit model. While these use cases are not comprehensive in defining all the potential uses of transit data, they were critical in providing focus for the development team. In future versions of the standard, additional use cases will be developed to facilitate expansion of the transit model.

## Supported Operation

*Overview and Description*

A customer seeks information related to point-to-point travel plans that includes public transportation services such as bus, rail or other mode. The trip itinerary request may be based on several key criteria such as origin, destination, travel date/time, amenities desired, traveler profile, trip constraints (i.e. lowest cost, shortest time, fewest transfers, mode, accessibility, time of day, day of week), and one way or return trip. Trip plan may include real-time information on schedule adherence, route adherence and service changes (see Rerouting Use Case) due to “incidents”.

This use case does not include paratransit or demand responsive scheduling and dispatch requirements.

*Concept of Operations*

Detailed below is the concept of operations for the Trip Itinerary Planning Use Case.

- Customer generates a trip request identifying origin, destination and time/date of travel (potentially specifying preference criteria pertaining to cost, transfer, mode/carrier, etc.).

- The Trip Planning System verifies that request is complete and accurate. When verified it processes customer request and generates a trip plan.

- The Trip Planning System verifies that the scheduled data is still valid on all legs for near term (review trip plan against reroutes, updates and planned events). If there are exceptions, the system regenerates the itinerary.

- For trip plans in the near future, the system checks real-time status of service. If there are exceptions, it regenerates the itinerary.

*Enumeration of Needs*

The following functions are needed to respond to customer requests for trip itinerary requests.

Request and verify customer trip criteria.

- Provide options for selecting origin and destination
  - Potential origin and destination names should be comprehensive including addresses, vanity addresses, intersections, landmarks (e.g., malls, squares, hospitals, etc.), community centers (e.g., Hyde Park in Chicago).
- Provide service and amenity options for different modes
  - Date
  - Departure or Arrival time
  - Service area
  - Routes/trips
  - Public Transportation Stops
- Provide options for criteria selection ("minimizing") including
  - Shortest trip (travel time , trip distance)
  - Shortest walking/driving distance (access/egress)
  - Least number of transfers
  - Least costly
- Provide options for including/excluding various criteria including
  - Mode
  - Via Landmark
  - Amenity at stop point (e.g., parking availability, accessibility)
  - Service types (e.g., express or local)
  - Route
  - Fare Media (e.g., pass, cash, credit card)
  - Accessibility

Provide transit trip itinerary plan based on customer criteria.

- Provide driving or walking/biking directions and distances to/from selected public transportation stops to/from origin/destination
  - Identify obstacles, barriers, accessibility, amenities for directions to/from public transportation stops
- Provide directions for walking between transfer points
- Provide transit information on planned bus route numbers, travel direction, schedules and current operations including route numbers, departure/arrival times and locations, and transfers within a mode and between modes
- Provide service information on different modes including planned and unplanned detours and real-time schedule adherence information
- Provide amenity information on public transportation stops

- Provide fare cost information for planned trip
- Provide estimated travel time for the itinerary
- Provide a written trip itinerary summary containing the sequential unlinked trip making activities including origin, boarding bus stop location and ID number, first transit route, alighting location, transfer to 2nd bust route information including boarding & alighting, and so on, until the final destination.

To meet these user needs, the following data needs should be supported:

- Provide a Topologically Complete and Logically Consistent Transportation Network including street names and addresses, alternate street names, cities, zip codes, barriers
- Provide a Complete List of Street Names and Landmarks including park and rides, transit centers, and neighborhood locations
- Provide a Complete and Logically Consistent Transit Network and Features
    - Patterns, public transportation stops and time points over all transit modes, and transfer points
    - Revenue trip times (particularly detailed bus trip schedules referenced to trip pattern spatially on a stop-by-stop or timepoint-by-timepoint level), and estimated transfer and wait times at stop points (by time of day)
- Provide Fare Information for all combinations of itineraries (including transfers)
- Provide Real-time schedule adherence data
- Provide park-n-ride , transit center data on location, size, amenity, and other characteristics description
- Provide bus stops list on ADA, amenity, shelter, and other relevant characteristics.
- Provide Unplanned rerouting information (see Unplanned Re-routing use case)

## Functional Requirements for Supported Operation

*Overview of Requirements*

The requirements for supporting the Trip Itinerary Plan Use Case are

- Request and verify trip itinerary request
- Provide trip itinerary plan to customer

*Detailed functional requirements*

**Table 2-Trip Itinerary Planning (TIP) Functional Requirements**

| Requirements |
| --- |
| ***TIP.1*****-- Request and verify trip itinerary criteria** |
| TIP 1.1 - The system shall provide options to the customer to create an itinerary |

request. The information components needed for this requirement are:

- Information on service area, modes, routes, public transportation stop points
- Information on origin, destination, date and time of travel
- Information on service types and trips per route (including attributes of each trip in the route, e.g., wheel chair accessibility, bike or ski rack)
- Information on fare media accepted
- Information on public transportation stop points, their amenities and accessibility
- Information on allowable criteria selection features (include and exclude; minimize)

TIP 1.2 - The system shall verify that the customer request is complete and accurate. In addition to the information components listed in TIP 1.1, this requirement needs the following information components:

- Information on addresses, vanity addresses, landmarks, alternate street names
  - Complete List of Street Names and Landmarks

***TIP.2*— Provide transit trip itinerary plan to the customer**

TIP 2.1 - The system shall develop a transit trip itinerary based on customer criteria. To accomplish this, the systems must determine several alternative itineraries. The internal functions are

- The location of entry and exit into the transit network
- The most efficient path from entry to exit in the transit network (based on selected criteria), this may require incorporating walking and wait times at transfer locations
- Walking directions for transfer
- Walking and driving directions from/to origin/destination to/from entry/exit points including barriers, obstacles and modal network connections within the *transportation* network
- List of amenities at specific public transportation stop points associated with plan
- Calculate fares and allowable fare media (including transfers) per leg as well as total cost
- Calculate total travel time
- Calculate total walking time
- Generate return trip (if requested)

The information components needed for this requirement are:

- For Origin/Destination and Walking and Driving Directions –
  - Topologically Complete and Logically Consistent Transportation Network including street names and complete addresses

- For Developing the Transit Trip Plan
    - o Complete and Logically Consistent Transit Network and Features
        - Patterns, public transportation stop points and time points over all transit modes, and transfer points
        - Revenue trip times (each bus trip can be geo-referenced by trip pattern spatially on a stop-by-stop or timepoint-by-timepoint level), and estimated transfer and wait times at stop points (by time of day)
    - o Fare Information for all combinations of itineraries (including transfers)

---

TIP 2.2 – The system shall verify the trip itinerary plan against any planned or unplanned detours, delays or special services. The information components needed for this function are:

- Unplanned rerouting along the trip plan
- Status of Planned/construction of RoadSeg along the trip plan
- Special service schedules (auxiliary parking facilities that are used as pick-up/drop-off points)

<<The information components needed to support this function are not included in the Data Mapping section>>

---

TIP 2.3 - The system shall provide real-time updates on itineraries that are scheduled for the near future (e.g., within an hour). The information components needed for this function are:

- Estimated departure/arrival times of vehicles designated to perform selected trips in itinerary.

<<The information components needed to support this function are not included in the Data Mapping section>>

## Mapping Data Requirements to Current Transit Model

The data requirements necessary for trip itinerary planning use case are described in the table below.

**Table 3-Trip Planning Data Requirements**

| Data Requirements | Definitions | Assumptions/Conditions |
|---|---|---|
| Public Transportation Stop | An established location where public transport customers may board or alight from a transit vehicle in revenue service. | Attributes: *see PTS Use Case*<br>Include:<br>▪ Wait times<br>▪ Fare Zone (if applicable) |
| Amenity | The elements of a physical feature, a fixed location, or a transit facility. The amenities of a public transportation stop, for example, may include the shelter, platform announcement panel, and benches. An amenity may be described by one or more characteristics, or attributes, such as the year of construction or its current condition. | Unique ID, Name, type. Domain types: list the known types and add 'other'. |
| Transfer points | A transfer point is a geographic location that encompasses more than one bus stop where a customer can move from one route to another. Defined the same as cluster. | Transfer points could have an associated impedance. Then it might not be accessible. Transfer points or clusters need to be composed of PTStops that make up a transfer cluster, and unique identifier. Impedance, walking directions between stop points should also be included |

| Data Requirements | Definitions | Assumptions/Conditions |
|---|---|---|
| Patterns (including routes) | A unique, non-branching, ordered sequence of timepoints, street links, public transportation stops from the beginning of a route to the end of a route. | Patterns provide the path of the trips, temporal service information is contained in the trips. Patterns serve a function similar to 'anchor points' in the Road MAT Standard. The density of timepoints is directly related to the accuracy needed in the schedule.<br><br>The pattern is an ordered sequence of road segments, as well as time points, and stops. But transit agencies usually use the whole segment, rather than portions of segments, even when the PTStop occurs in the middle of the block.<br><br>Fields include:<br>▪ ID<br>▪ Route number ID<br>▪ Service type – local/express<br>▪ Schedule version<br>▪ Revenue/non-revenue<br><br>Model Element:<br>▪ Ordered sequence of streets (RoadSeg) that make up the pattern, which furnishes geometry<br><br>Note: At WMATA path/route is an ordered sequence of timepoints. For trip planning there is an ordered set of road segments or an ordered set of TimePoints. |

| Data Requirements | Definitions | Assumptions/Conditions |
|---|---|---|
| Streets | | **Street links:**<br>▪ ID<br><br>RoadSeg:<br>▪ Status<br>▪ authorityID<br>▪ fieldMeasure<br>▪ length<br>▪ geometry (optional)<br>▪ topology (optional)<br>▪ isAnchorSection (Boolean)<br><br>All other attributes that pertain to roads are classified as linear or point events. |
| Address Ranges | | See Address Addendum |
| Landmarks | | **Landmark attributes**:<br>▪ Name<br>▪ Type<br>▪ Location |
| Parking lots | | Attributes:<br>▪ ID<br>▪ Public Transportation Stop(s) served<br>▪ Transit routes served and schedules<br>▪ Owner (optional)<br>▪ Facility phone (optional)<br>▪ Total Spaces<br>▪ Operating Hours<br>▪ Parking Provided for each vehicle class (spaces, rates, permissible entrances, fill time, other information) (optional)<br>▪ Availability of charging facility for electric cars (optional)<br>▪ Bicycle storage and lock facility (optional) |
| Walking distance | RoadSeg | |

| Data Requirements | Definitions | Assumptions/Conditions |
|---|---|---|
| Accessibility | | Curb cuts and corners are needed for ADA compliance. They should be attached to the road segment. |
| Obstacles to walking, grade data | | An attribute is added to the RoadSeg; "walking permitted – yes/no". The attribute is applied to each individual road segment. An obstacle could be a linear event, but is often just a Boolean attribute on a segment. Typically, one can walk along or walk over. The value applies to the entire segment. |
| Fare data (based on distance, or zones, of flat) | | Types of fare policies:<br>▪ Flat<br>▪ Distance<br>▪ Zone<br>▪ Time of day<br>▪ Transfers<br>▪ Special rider classes (elderly, youth, disabled)<br>▪ Bulk pass discount<br>Six-dimension table is required to handle the relationships between all the variations in fare types.<br><br>See Addendum for guidance on TCIP Fare Collection Fare Tables (NTCIP 1408) |
| Schedules | From TCIP: "A table that includes all the time points and trips on a route. Contained within the SchRoute is the Master Schedule Header information. Contained within SchTrip is the day type information." | For each route:<br>▪ Time Table Version<br>▪ Activation date<br>▪ Deactivation date<br>▪ All supported trips assembled by route direction, service type, and day type<br>▪ All supported trips in correspondence to the trip pattern number |
| Trips | "A one way scheduled movement of a transit vehicle between starting and ending time points." | Attributes:<br>▪ ID<br>▪ Trip type<br>▪ Ordered sequence of time points with their times (of arrival)<br>▪ Pattern ID (associated with)<br>▪ Time Table Version |

| Data Requirements | Definitions | Assumptions/Conditions |
|---|---|---|
| Pedestrian (sidewalks, bike paths, walking paths, centerline dividers) | | Attributes:<br>▪ TBD |

## Guidance on how to specify a Fare Table using TCIP Standard on Fare Collection Business Objects [NTCIP 1408:2001]

The TCIP Fare Collection Standard [28] supports a variety of Fare Tables. Each is packaged as data stream of fare character costs that is based on the fare policy and fare media used. The Fare Table includes identifiers to the data stream definition through the `table-type-id` (zone or distance based fare tables) and `list-of-fare-character-cost` (fare media type) fields.

The steps for defining fare tables are defined in the table below. Each of these steps are discussed in more detail in the sections below.

**Table 5-Fare Definition Steps**

| |
|---|
| 1. Develop fare tables for a specific agency/mode based on the validity date of the fare policy (i.e., `activation-datetime`, `deactivation-datetime`). |
| 2. Identify fare policy type and develop indices to define boarding/alighting pairs:<br>▪ Zone<br>▪ Distance<br>▪ Flat fare is a generalization from either the zone or distance based fare (one dimensional matrix |
| 3. Calculate the Cost based on Fare Media Type |
| 4. Define the Time Period Table |
| 5. Define the Fare Instruments |
| 6. Identify Exceptions |

```
FcFareTable  ::=SEQUENCE {
  id  FC-FareTableID,
  time-period-table-id  FC-TimePeriodTabelID,
  table-type-id  CHOICE  {
     zone-table-id  FC-FareZoneTableID,
     distance-table-id FC-FareDistanceTableID }  OPTIONAL,
  mode  CPT-Mode OPTIONAL,
  agency-id CPT-AgencyID OPTIONAL,
  activation-datetime  CPT-DateTime OPTIONAL,
  deactivation-datetime  CPT-DateTime OPTIONAL,
  list-of-fare-character-cost SEQUENCE OF FcFareCharacterCost,
  input-parameters  OCTET STRING OPTIONAL
     --these are the base values of the table when an algorithm is
     -- specified in the FcFareCharacterCost record
}
```

1. Develop fare tables for a specific agency/mode based on the validity date of the fare policy (i.e., `activation-datetime`, `deactivation-datetime`).

2. Identify fare policy type and develop indices to define boarding/alighting pairs:

- Zone
- Distance

Flat fare is a generalization of either the zone or distance based fare (one dimensional matrix).

Zone Based Fare Tables

Identify all combinations of boarding zones and alighting zones. Each cell has an index.

**Table 6-Fare Zone Table**

| Boarding / Alighting Zone | Zone 1 (`boarding-zone-id`) | Zone 2 |
|---|---|---|
| Zone 1 (`alighting-zone-id`) | 1 (`index`) | 2 |
| Zone 2 | 3 | 4 |

`FcFareZoneTableEntry` defines each cell index by boarding and alighting zones.

```
FcFareZoneTableEntry ::= SEQUENCE {
  index  FC-FareZoneIndex,
  boarding-zone-id CPT-FareZoneID,
  alighting-zone-id CPT-FareZoneID }
```

`FcFareZoneTable` lists all the cells contained in the table. Because the table may be valid at certain times or certain days (e.g., peak hour fares) an optional field may be set to specify the validity of the activation and deactivation of date/time. Furthermore, there is a business rule that for each Fare Zone Table (identified by a separate index – `FC-FareZoneTableID`), each cell index (`FC-FareZoneIndex`) in the `list-of-cell-indices` must be unique.

```
FcFareZoneTable ::= SEQUENCE {
  id  FC-FareZoneTableID,
  list-of-cell-indices  SEQUENCE OF FC-FareZoneIndex,
  activation-datetime  CPT-DateTime OPTIONAL,
  deactivation-datetime  CPT-DateTime OPTIONAL,
  agency-id  CPT-AgencyID OPTIONAL  }
```

Distance Based Fare Tables

The Distance based Fare Tables are organized in a similar fashion. A basic matrix is defined by the `FcFareDistanceTable`. Each entry or cell in the table is defined by a `FcFareDistanceTableEntry`. An assumption is made that there are a finite number of stop points in the system, and so, the `FcFareDistanceTable` is defined as a matrix of boarding and alighting stop points.

**Table 7-Fare Distance Table**

| Boarding / Alighting Stop | Stop # 1001 (`boarding-` | Stop #1002 |
|---|---|---|

| Point | stop-point-id) | |
|---|---|---|
| Stop # 1001 (alighting-stop-point-id) | 1 (index) | 2 |
| Stop # 1002 | 3 | 4 |

```
FcFareDistanceTableEntry   ::=SEQUENCE {
  index  FC-FareDistanceIndex,
  boarding-stop-point-id  CPT-StopPointID,
  alighting-stop-point-id  CPT-StopPointID }
```

The `FcFareDistanceTable` also includes a mandatory field on the type of distance that is calculated: linear (along the path) or line-of-sight. Similar to the Zone based Fare Table, the Distance Table is identified by a unique `index` and each cell in the `list-of-fare-cell-indices` should be unique.

```
FcFareDistanceTable ::=SEQUENCE {
  id FC-FareDistanceTableID,
  type  FC-FareDistanceType,
  activation-datetime  CPT-DateTime,
list-of-fare-cell-indices  SEQUENCE OF FC-FareDistanceIndex }
```

3. Calculating the Cost based on Fare Media Type

The cost of a ride may be based on:

- Rider classification (e.g., regular, senior, child)
- Service Type (e.g., regular, express, local, loop)
- Time (period) of day traveling (see definition of `FcTimePeriodTable` below)
- Fare Instrument (see definition of `FcFareInstrument` below)
- Distance or zones traveled through (`FcFareZoneTable` and `FcFareDistanceTable`)

So the cost is based on a five dimensional table. The best way to approach defining the cost is to approach the first four fields: Rider classification, Service type, Time Period and Fare Instrument fixed and fill in the cost for the distance or zone policy.

For example, the fare at Metro MTA on a bus for a regular rider, riding on an express during morning peak using cash will pay a monetary cost of `monetary-value`. Each unique definition for the `FcFareCharacterCost` will be associated with a unique `index` (`FC-FareCharacterCostIndex`).

The amount of each character cost entry is defined by at least one of the following:

- Monetary cost
- Ride cost
- Algorithm for calculating the value of either ride or monetary cost

```
FcFareCharacterCost ::=SEQUENCE {
```

```
        index  FC-FareCharacterCostIndex,
        rider-classification  FC-RiderClassification,
        service-type SCH-ServiceType OPTIONAL,
        time-period-index  FC-TimePeriodIndex OPTIONAL,
        fare-type-index  CHOICE {
           fare-zone-index  FC-FareZoneIndex,
           fare-distance-index  FC-FareDistanceIndex}  OPTIONAL,
        list-of-fare-instrument-ids  SEQUENCE OF FC-FareInstrumentID,
        monetary-value  FC-FareCost OPTIONAL,
        ride-value  FC-RideValue  OPTIONAL,
        algorithm  OCTET STRING OPTIONAL  --(executable or algorithm for
             -- calculating fare)
    } (WITH COMPONENTS {..., monetary-value PRESENT}|
    WITH COMPONENTS {..., ride-value PRESENT}|
WITH COMPONENTS  {..., algorithm PRESENT})
```

**Table 8-Data Element Code Values for select `FcFareCharacterCost` fields**

| Data Element Name | Definition | Code Values |
|---|---|---|
| `FC-RiderClassification` | A means of classifying the types of riders on public transportation vehicles. | `FC-RiderClassification ::= INTEGER {`<br>`regular (1),`<br>`senior (2),`<br>`child (3),`<br>`student (4),`<br>`youth (5),`<br>`ada-customer (6),`<br>`promotional (7),`<br>`employee (8),`<br>`retired-employee (9),`<br>`public-assistance-customer (10)`<br>`-- 11-155 reserved`<br>`-- 156-255 local use`<br>`} (0..255)` |
| `SCH-ServiceType` | Type of transit service provided. | `SCH-ServiceType ::= INTEGER`<br>`{ regular (1),`<br>`express (2),`<br>`circular(3),`<br>`radial (4),`<br>`feeder (5),`<br>`jitney (6),`<br>`limited (7),`<br>`nonRevenue (8),`<br>`unknown (9),`<br>`charter (10),`<br>`school (11),`<br>`special (12),`<br>`operatorTraining (13),`<br>`maintenance (14),`<br>`noService (15),`<br>`standBy (16),`<br>`extra (17)`<br>`-- 18-149 reserved`<br>`-- 150-255 local use`<br>`} (0..255)` |

4. Defining the Time Period Table

The time period table may be defined for the calendar or by day type. Each cell (each column in Table 4) in the time period table is defined by `FcTimePeriodEntry`.

**Table 9-Example of a Time Period Table for Weekday (day type)**

| `begin-time` to `end-time` | 5:30-7:30 (early am) | 7:30-9:30 (morning peak) | 9:30-3:30 (mid-day) | 3:30-7:00 (afternoon peak) | 7:00-12:00 pm (night) |
|---|---|---|---|---|---|
| `index [FC-TimePeriodIndex]` | 1 | 2 | 3 | 4 | 5 |

```
FcTimePeriodEntry ::=SEQUENCE{
index  FC-TimePeriodIndex,
begin-time  TIME,
end-time  TIME,
day CHOICE  {
   calendar-date CPT-CalendarDate,
   day-type  SCH-DayType }
}
```

The collection of `FcTimePeriodEntry` completes the `FcTimePeriodTable`. Each `FC-TimePeriodIndex` must be unique for a single time period table (`FC-TimePeriodTableID`). A calendar may be designed for this format. Each segment of time within a calendar date may be assigned a unique identifier.

```
FcTimePeriodTable  ::= SEQUENCE {
id  FC-TimePeriodTableID,
list-of-time-period-indices  SEQUENCE OF FC-TimePeriodIndex,
agency-id  CPT-AgencyID OPTIONAL,
activation-date CPT-ActivationDate  OPTIONAL,
deactivation-date  CPT-DeactivationDate   OPTIONAL
}
```

5. Defining Fare Instruments

Many transit agencies support various types of fare categories and instruments. There are daily, weekly and monthly passes, combination passes, tickets, trip checks, transfers, tokens, rider cards, rider discount cards, “golden” passes, and of course, cash. There are four ways of defining fare instruments:

- Based on ride value
- Based on cash value
- Based on unlimited number of rides over a period of time

- Other

Also, fare instruments may be used in combination, e.g., ten cents with a senior pass.

**Table 10-TCIP definition of various Fare Instruments**

| Fare Instrument Name | Fare Instrument Definition |
|---|---|
| `FcFareInstrument` | The definition of a valid fare instrument that can be used by a specific public transportation service. A fare instrument may be defined as multiple value instruments, e.g., ten cents with a senior pass. |
| `FcMonetaryInstrumentDefinition` | The definition of a type of instrument that possesses a monetary value including cash (bills and coins), tokens, tickets, passes, etc. |
| `FcFareMediaOtherDefinition` | A fare instrument which does not fall into monetary, ride, or pass categories. (This may include an employee or retired indentification card.) |
| `FcPassInstrumentDefinition` | A fare instrument which contains unlimited number of rides over a period of time, e.g., monthly, weekly, and daily passes. |
| `FcRideInstrumentDefinition` | The definition of a fare instrument that possesses a ride value for a trip on a public transportation vehicle serving a transit agency or a region fare structure. |

Ride Instrument Definition

The ride instrument may be a token, ticket (like a transfer), pass fare card or transit check. The value is expressed as a ride. There may be restrictions on the ride such as mode choice, route or line choices, or Transit agency providing the service.

```
FcRideInstrumentDefinition  ::=SEQUENCE {
  id  FC-RideInstrumentID,
  type  FC-RideInstrumentType,
  description  FC-RideInstrumentDescription,
  value  FC-RideValue,
  agency-id  CPT-AgencyID,
  list-of-modes-accepted  SEQUENCE OF CPT-Mode  OPTIONAL,
  list-of-routes-accepted  SEQUENCE OF SCH-RouteName  OPTIONAL,
  list-of-lines-accepted  SEQUENCE OF SCH-BlockName  OPTIONAL }
```

`FC-RideInstrumentType`

- token (1)
- ticket (2)
- pass-fare-card (3)
- transit-check (4)

Pass Instrument Definition

The pass instrument is typically a card, magnetic stripe, flash, transit check or smart card. The pass permits unlimited travel for a certain period of time. Although many places issue magnetic stripe or smart cards for the value of one ride or for a purse of cash, this category should not be confused with those alternative instrument classifications. In the `FcPassInstrumentDefinition` message, the `expiration-datetime` defines the time and date that the card expires. If the instrument is activated on first use, then the field is set on entry to the system. With the Pass Instrument, there may be restrictions associated with its use such as mode, routes and lines. A transfer may also be defined as a pass instrument if the transfer is based on its use over a period of time, e.g., two hours since issue.

```
FcPassInstrumentDefinition ::=SEQUENCE {
  id FC-PassInstrumentID,
  type  FC-PassInstrumentType,
  description-  FC-PassInstrumentDescription  OPTIONAL,
  agency-id  CPT-AgencyID  OPTIONAL,  --issuer of pass instrument
  value  FC-PassValue,
  expiration-datetime  FC-ExpirationDateTime  OPTIONAL,
  list-of-modes-accepted  SEQUENCE OF CPT-MODE  OPTIONAL,
  list-of-routes accepted  SEQUENCE OF SCH-RouteID  OPTIONAL,
  list-of-lines-accepted  SEQUENCE OF SCH-BlockName  OPTIONAL}
```

`FC-PassInstrumentType`

- mag-stripe (1),
- flash-pass (2),
- transit-check (3),
- smart-card (4)

Monetary Instrument Definition

The monetary instrument is defined by categories set by an international standardization body. The `FC-MonetaryInstrumentType` is defined as:

> “A list of authorities and global currencies as specified by a 3 character ISO 4217 [29] currency code or six character CPT-AgencyID. The ISO 4217 format includes a two character country code based on ISO 3166 [30] plus a one-character currency designator.”

This definition supports transit agencies that mint their own tokens. The default monetary authority is the USA in cents.

```
FcMonetaryInstrumentDefinition ::=SEQUENCE {
  id  FC-MonetaryInstrumentTypeID,
  type  FC-MonetaryInstrumentType,
```

```
      description  FC-MonetaryInstrumentDescription,
      authority  FC-MonetaryInstrumentAuthority,
      value   FC-MonetaryInstrumentValue }
```

Types of monetary instruments include:

```
   FC-MonetaryInstrumentType
```

- `bill (1),  --bill`
- `coin (2),  --coin`
- `token (3),  --token`
- `ticket (4),  --ticket`
- `debit (5),`
  - `debit: money is in user's acct and transferred to TA acct;`
  - `card is external to TA`
- `stored-value (6),`
  - `--stored value: prepaid cash; internal cash instrument`
  - `--issued by property`
- `charge (7), -- charge:  federal institution extends credit`
- `hybrid (8),  --hybrid`
- `transit-check (9),  -- transit check`
- `check-card (10)  --check card`

<u>Other Fare Media Defintions</u>

As described above, `FcFareMediaOtherDefinition` describes any other type of fare media. No value is provided for this type of instrument, special rules must be defined by the agency and vendor for the vendor product.

```
   FcFareMediaOtherDefinition  ::= SEQUENCE {
      id  FC-FareMediaOtherID,
      description  FC-FareMediaOtherDescription,
      agency-id  CPT-AgencyID OPTIONAL }
```

<u>Fare Instrument Definition</u>

The Fare Instrument defines all the fare instruments that are permitted for paying for services. In the fare instrument definition, multiple payment methods may be defined. So, using the example cited in this section: "ten cents with a senior pass", the *senior pass* may be defined as a `FcFareMediaOtherDefinition` and *ten cents* as `FcMonetaryInstrumentDefinition` with a value of ten cents. The Fare Instrument definition is provided with a unique identifier (`id  FC-FareInstrumentID`). The `id` may then be inserted into the `FcFareCharacterCost.list-of-fare-instrument-ids` as a permissible fare instrument.

```
   FcFareInstrument  ::=SEQUENCE {
      id  FC-FareInstrumentID,
      agency-id  CPT-AgencyID,
      monetary-instrument-type-id FC-MonetaryInstrumentTypeID  OPTIONAL,
      ride-instrument-id  FC-RideInstrumentID OPTIONAL,
      pass-instrument-id  FC-PassInstrumentID OPTIONAL,
      fare-media-other-id  FC-FareMediaOtherID OPTIONAL,
```

```
      riders-on-fi-max   FC-RidersOnFIMax OPTIONAL,
      activation-datetime  CPT-DateTime OPTIONAL,
      expiration-datetime  FC-ExpirationDateTime  OPTIONAL,
      list-of-fi-standards  SEQUENCE OF FC-FIStandard  OPTIONAL
      instrument-physical-dimensions   FOOTNOTE  OPTIONAL }
    (WITH COMPONENTS  {..., monetary-instrument-type-id PRESENT}|
    WITH COMPONENTS {..., ride-instrument-id PRESENT}|
    WITH COMPONENTS {..., pass-instrument-id PRESENT}|
    WITH COMPONENTS {..., fare-media-other-id PRESENT})
```

## 6. Identifying Exceptions

There are always exceptions to the best fare policies. As such, the standard recognizes a way of defining exceptions. Exceptions are described for any combination of the fields that were described above. For example, boarding/alighting location pair, service type, mode, time period traveled, fare instrument type. The `money-deduct` and `ride-deduct` fields define the cost of the specific service defined by the other fields.

```
    FcFareExceptionCell  ::=SEQUENCE {
    index FC-FareExceptionCellIndex,
    boarding-stop-point-id  CPT-StopPointID,
    alighting-stop-point-id  CPT-StopPointID OPTIONAL,
    footnote  FC-Footnote,
    service-type  SCH-ServiceType OPTIONAL,
    mode  CPT-Mode  OPTIONAL,
    list-of-time-period-indices  SEQUENCE OF FC-TimePeriodIndex OPTIONAL
    monetary-instrument-id  FC-MonetaryInstrumentTypeID OPTIONAL,
    ride-instrument-id  FC-RideInstrumentID OPTIONAL,
    pass-instrument-id  FC-PassInstrumentID OPTIONAL,
    fare-media-other-id  FC-FareMediaOtherID OPTIONAL,
    money-deduct  FC-ValueDeduct  OPTIONAL
    ride-deduct  FC-RideValueDeduct OPTIONAL
    }
    (WITH COMPONENTS {..., monetary-instrument-id, money-deduct PRESENT}|
    WITH COMPONENTS {..., ride-instrument-id, money-deduct PRESENT}|
    WITH COMPONENTS {..., pass-instrument-id, money-deduct PRESENT}|
    WITH COMPONENTS {..., fare-media-other-id, money-deduct PRESENT}|
    WITH COMPONENTS {..., monetary-instrument-id, ride-deduct PRESENT}|
    WITH COMPONENTS {...,ride-instrument-id, ride-deduct PRESENT}|
    WITH COMPONENTS {...,pass-instrument-id, ride-deduct PRESENT}|
    WITH COMPONENTS {...,fare-media-other-id, ride-deduct PRESENT})
```

Each cell is defined by a unique index and stored in the `FcFareExceptionTable`. The Exception Table is associated with a Fare Table. The thought is that the exception table is incorporated by the vendor as an exception to relevant `list-of-fare-character-cost` fields in the main Fare Table.

```
    FcFareExceptionTable ::=SEQUENCE {
    id   FC-FareExceptionTableID,
    activation-date  CPT-ActivationDate,
    deactivation-date  CPT-DeactivationDate OPTIONAL,
    table-id  FC-FareTableID OPTIONAL,
       --index identifying excpetion to a fare table
    time-period-table-id  FC-TimePeriodTableID OPTIONAL,
```

```
    agency-id  CPT-AgencyID OPTIONAL, --that accpets exception
    list-of-fare-cell-indices  SEQUENCE OF FC-FareExceptionCellIndex
    }
```

# Annex B - Public Transportation Stop Inventory Sharing Use Case

In developing the standard, specific transit use cases were utilized to assist in defining the transit model. While these use cases are not comprehensive in defining all the potential uses of transit data, they were critical in providing focus for the development team. In future versions of the standard, additional use cases will be developed to facilitate expansion of the transit model.

## Supported Operation

*Overview and Description*

Different transit organizations capture spatial and attribute information about public transportation stops using a variety of methods, with varying levels of accuracy, and for different business reasons. Quite often the geographic areas in which different agencies operate are overlapping. Even if they do not overlap, two agencies may provide services that are complimentary. There is a growing list of reasons organizations need to share information about public transportation stops. They include but are not limited to:

- Public Safety
- Avoiding duplication of effort (data collection)
- Data maintenance
- Coordination of maintenance activities.
- Supporting ITS applications
- Coordination of marketing activities.
- More reliable data for trip planning activities.
- Cartographic Output.
- Ridership analysis
- System planning.

Complicating the sharing of this information the fact that different organizations define public transportation stops differently. More importantly they may capture the spatial information about the same real world feature differently. For example, for one organization, the location of a bus stop is the location of the pole holding the bus stop sign. Another organization may capture the bus stop as the location of the bus when passengers are boarding and alighting. Another possible spatial definition is a GPS coordinate that would be captured by an on board GPS receiver at varying times of the day. A fourth representation may be a linear referenced feature along a centerline network, thus tying the accuracy of the bus stop to the accuracy of the centerline network. Because of these factors it is imperative that the information in a bus stop inventory be sharable independent of the geography.

*Enumeration of Needs*

The following are functions that would be performed using a regional public transportation stop inventory. Many of these functions are currently performed however a regional public transit stop database would make these functions more efficient. To be consistent with other use cases, an1actor has been identified who would perform each function.

**Table 11-Potential Users of Shared Data**

| Actor | Responsibilities |
|---|---|
| Maintenance Personnel | Maintain a facilities inventory of all maintainable facilities associated with public transportation stops. This would allow coordination with other maintenance operations divisions within the same geographic area. |
| Customer Service Personnel | Identify stop amenities to the public for specific stops. |
| Public Safety Personnel | Comprehensive maps and images of real world features when responding to emergency incidents. This would also provide the ability to plan and analyze public transit data across a large geographic area in conjunctions with emergency operations. An example would be the sniper incidents around Washington, D.C. in the fall of 2002. |
| Route Planners / System Planners | Plan for increased or decreased service based on the service of neighboring jurisdictions. |
| Operations Personnel | Provide necessary data to ITS applications. |

## Functional Requirements for Supported Operation

*Overview*

There is one main requirement for a regional public transportation stop inventory: a unique identifier for the public transportation stop. The unique identifier must be something that each organization can maintain independently. It must not be a number or series of characters that has an alternate meaning.

**Table 12-Detailed Functional Requirements**

| Requirements |
|---|
| ***PTS.1*** **– Public transportation stop data sharing.** |
| PTS 1.1 – A regional public transportation stop inventory shall support the sharing of stop information across multiple agencies. The information components required for |

this requirement are:

- A unique identifier
- Latitude / Longitude (if exists)
- Heading (if exists)
- Date last update (if exists)
- USNG Address (if exists)

Optional data shall also be included if it exists such as the following:

- Ridership data
- Route data
- Status (active, retired, etc.)
- Amenity information
- Engineering data (sidewalk, curb, etc.)

The format of the optional data is not overly important as long as each table of associated information is linked to the regional ID.

## Mapping Data Requirements to Current Transit Model

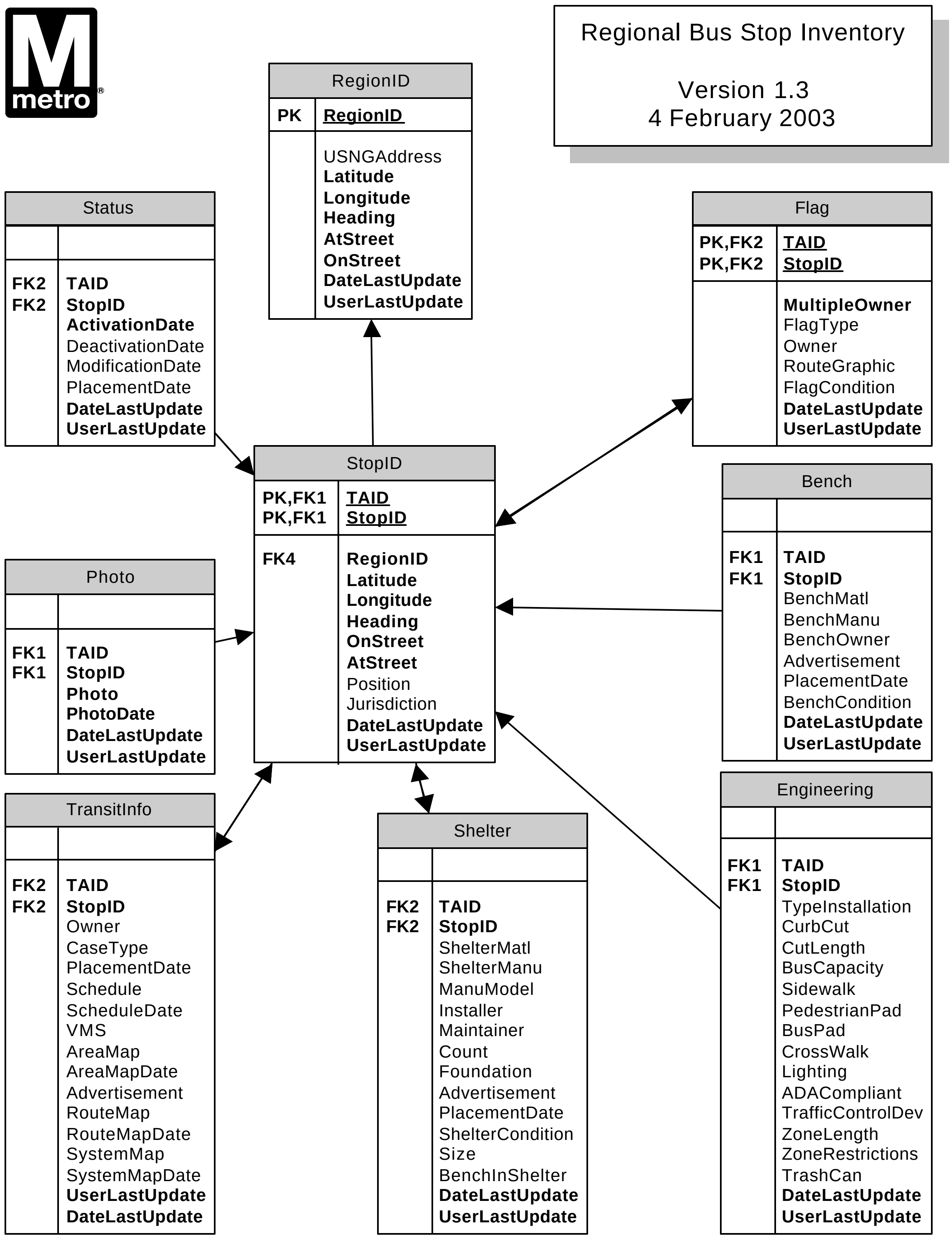


**Figure 4-Sample Regional Bus Stop Database Structure**

## Annex C - Unplanned Re-Routing Use Case

## Supported Operation

*Overview and Description*

As part of ongoing business operations, Transit agencies often must deviate from scheduled routings to accommodate a variety of dynamic situations. The duration for these deviations could be short or long depending on the event and the ability for the vehicle to return to the scheduled pathway. Examples of unplanned events requiring deviations from scheduled pathways include:

- Roadway accidents
- Unplanned or emergency construction activities
- Weather.

These events usually result in an obstacle or blockage that closes the roadway to thru traffic necessitating the use of a detour. These detours are usually created in a spontaneous fashion, designed on the fly by field personnel, and then communicated to operations centers for ongoing use until the detour is no longer necessary. In emergency situations, first responders may designate detour routes. Detour routings will likely affect the path the transit revenue vehicle takes, but they may also impact arrival/departure times, frequency of service, Public Transportation Stop locations/accessibility, and others.

A more complex situation involves a mode-substitution in response to an unplanned reroute. In fixed guideway service (e.g., rail), an outage due to vehicle blockage or guideway problems can result in the need to provide an alternate route via a different mode. Most agencies have contingency plans to accommodate such events, but the specifics of the reroute path, vehicles used, frequency of service, etc. is dependent upon the timing, location, and longevity of the event. The mode change scenario is not within the scope of this Use Case.

*Enumeration of Needs*

The following functions are necessary to respond to unplanned reroutes. For each function, an actor has been identified who would perform the function.

**Table 13-Unplanned Rerouting stakeholders**

| Actor | Responsibilities |
|---|---|
| Field Personnel (in consultation with Operations Center and first responders if present) | o Identify appropriate detour path and new Public Transportation Stops.<br>o Identify estimated duration of detour.<br>o Communicate path and Public Transportation Stops to Operations Center.<br>o Assist passengers needing to transfer to new mode or vehicle.<br>o Identify cause and supervising agency (e.g., EMS, utility, etc.) and key contact person; may also communicate duration |

| Actor | Responsibilities |
|---|---|
| | of event. <<not in scope of our Use Case>><br>o Continue to communicate unplanned event status. <<not in scope of our Use Case>> |
| Vehicle | o Receive and store new automated announcements, interior and exterior sign detail, and schedule adjustments. |
| Driver | o If driver receives run card via vehicle control head (mobile data terminal), acknowledge receipt of alternative route.<br>o Provide verbal announcements of new Public Transportation Stops and Transfer Points. |
| Customer Information | o Inform customers of detour route path and duration.<br>o Inform customers of changes to Public Transportation Stop locations and times. |
| Operations Center | o Identify affected routes and specific trips<br>o Provide operators with driving directions for detour route.<br>o Identify new patterns and routing.<br>o Adjust schedules for connecting services.<br>o Generate and provide driver and/or vehicles with new automated announcements, interior and exterior sign detail, and schedule adjustments<br>o Coordinate incident response with supervising agency <<not in scope of our Use Case>> |

## Functional Requirements for Supported Operation

*Overview*

The requirements for supporting the rerouting use case are

- Identifying the changes to the transit system
- Communicating those changes to various components of the system that need it.

**Table 14-Detailed Functional Requirements**

| Requirements |
|---|
| ***RR.1 – Identify necessary changes in scheduled paths and Public Transportation Stops.*** |
| RR 1.1 – Field Personnel and the Operations Center shall work together to identify the optimal detour path and changes in Public Transportation Stop locations. The information components required for this requirement are:<br>▪ Information about the incident such as location, type of incident (e.g. fire, flood, etc.), estimated duration<br>▪ Area affected, including streets and intersections<br>▪ Duration of event |

| Requirements |
|---|
| ▪ Obstacles to walking<br>▪ Navigable streets<br>▪ Public Transportation Stops excluded by the event<br>▪ Public Transportation Stops created as a result of the event |
| RR 1.2 – The Operations Center shall identify impacts on subsequent trips for the rerouted vehicles and impacts on Public Transportation Stops outside of the immediate area affected by the event. This may include adjusting schedules of connecting services. The information components required for this requirement are:<br>▪ Information about the incident such as location, type of incident (e.g. fire, flood, etc.), estimated duration<br>▪ Area affected<br>▪ Duration of event<br>▪ Navigable streets<br>▪ Facility locations<br>▪ Additional Public Transportation Stops and facilities excluded by the event |
| ***RR.2 – Communicate changes in schedule.*** |
| RR 2.1 – The Operations Center shall communicate information about schedule changes to drivers, Customer Information, and revenue vehicles. This information may have to be communicated via a variety of mechanisms depending on the location of the receiver and the duration of the event. For example, on-duty drivers may need to receive the information by radio or digitally over a wireless communications link, whereas drivers who will experience the change in service on subsequent days may receive the information via hardcopy. The information components required for this requirement are:<br>▪ Information about the incident such as location, type of incident (e.g. fire, flood, etc.)<br>▪ Area affected<br>▪ Estimated duration of event<br>▪ Public Transportation Stops excluded by the event<br>▪ Public Transportation Stops created as a result of the event<br>▪ Driving instructions<br>▪ Revenue vehicles affected<br><br>In addition, if the reroute is of sufficient duration to incorporate within the information and scheduling systems within the agency, then the following information is required:<br>▪ Ordered set of street segments making up the reroute path.<br>▪ Ordered set of timepoints making up the reroute path.<br>▪ Ordered set of Public Transportation Stops making up the reroute path<br>▪ New times or time offsets at affected timepoints<br>▪ New signage for the vehicle<br>▪ New voice announcements for the vehicle |
| RR 2.2 – The Customer Information systems shall communicate information about |

**Requirements**

schedule changes to customers. The information components required for this requirement are:

-- On Bus and Off Bus:

- Information about the incident such as location, type of incident (e.g. fire, flood, etc.)
- Area affected
- Estimated duration of event
- Public Transportation Stops excluded by the event
- Public Transportation Stops created as a result of the event

-- On Bus CIS

- Announcement of Public Transportation Stops excluded by the event
- Announcements of new/temporary Public Transportation Stops created as a result of the event
- Announce estimated delay
- New signage for the vehicle

-- Off Bus CIS

- Routes affected
- Estimated delay (new times) at Public Transportation Stops
- Alternate path (with new/temporary Public Transportation Stops)

## Mapping Data Requirements to Current Transit Model

The data entities necessary for the rerouting use case include block, trip, route, Public Transportation Stop, facility, and road segment.

**Table 15-Data Requirements for Rerouting Use Case**

| Requirement | Model Element |
|---|---|
| Obstacles to walking | RoadSeg |
| Navigable streets | RoadSeg |
| Excluded Public Transportation Stops | RoadSeg, Public Transportation Stops, facility, block |
| New Public Transportation Stops | RoadSeg, Public Transportation Stops, block |
| Driving instructions | RoadSeg |
| Affected vehicles | Block, vehicle |
| New times (or delay offset) | Trip, timepoint, |
| New signage | Block, vehicle |
| New Announcement and Sign Triggers | Pattern (if duration of event is sufficiently long) |

## Annex D – Address Extension to the Transit Model

Address information is useful for several transit-related applications, such as itinerary planning and facility management. Addresses may define the location of customers, their designations, and the fixed facilities used by transit service providers. Specifically, the Transit model needs to support transmittal of physical addresses, such as those defined by the proposed NSDI *Address Data Content Standard* for situs or delivery locations. This requirement includes a need to also identify the location of these physical address on the transportation system utilized by the transit service. The traditional approach, and the one supported by this proposal, is to define the addresses that exist along a particular street segment. This information is later used to place a physical address along the street segment.

Address segments represent a contiguous portion of a named street with a continuous range of physical address numbers and a single combination of street name, postal community, state, and postal code. An address segment applies to all or part of a street segment, which is represented in the proposed Road and Transit models as the RoadSeg feature class. There may be one or more address segment records for each RoadSeg feature. This model means that a single address segment cannot span multiple RoadSeg features, and that each RoadSeg feature can be subdivided into multiple, logically separate address ranges.

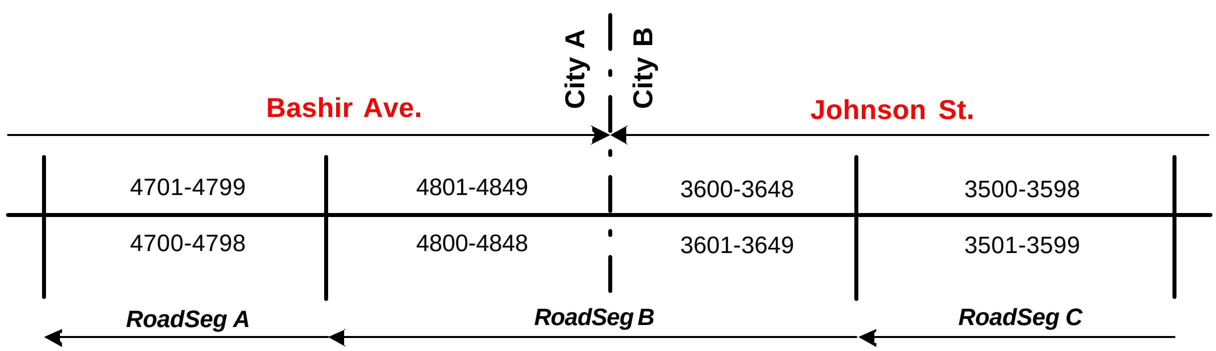


**Figure 5-Illustration of address segment information requirements.**

Figure 4 shows four address segments covering three city blocks, each of which is represented in the local Road database using a single RoadSeg feature. Addressing jurisdiction changes in the middle of RoadSeg B. (Jurisdiction could be stored in the Road database using RoadSeg linear events.) Each side of the road has its own address range, usually odd numbers on one side and even numbers on the other. In this example, street names and address segment patterns are unique to each city. Most street address database implementations use a single record with left- and right-side address ranges. However, a more robust data transfer mechanism would be constructed such that each address segment record contained the address range information applied to a single side of the road. This more complex structure allows the transmission of completely different address segment characteristics when, say, there are separate controlling political jurisdictions for each side of the road.

Addresses are located by GIS software along address segments using a process called geocoding. In this process, the first step is to find the address segment on which the subject address should be located. For example, given an address of 3521 Johnson St., the geocoding processor would search the database to find one or more address segments that could include this value. The data in Figure 1 provide at least one candidate, 3501-3599 Johnson St., which applies to the left side of RoadSeg C. (Geocoding processors identify the odd and even sides of the street addressing system by examining the terminal address range values and/or by referencing a field that indicates which side of the road contains odd numbers.) The second step is to do straight-line interpolation using the relative position of the subject address along a segment, assuming an equidistant spacing of address values. Thus, the address of 3521 Johnson St. would be placed at a position equal to the address's offset distance along the address segment, as determined by:

$$
\begin{aligned}
\textit{Location} &= (\textit{Address} - \textit{First Segment Address}) / (\textit{Address Segment Range}) \\
&= (3521 - 3501) / (3599 - 3501) \\
&= 21/98, \text{ or } 28\% \text{ from the start of the address segment}
\end{aligned}
$$

The first problem for the Transit MAT model, with regard to accommodating the transfer of address information, is to provide the means for transmitting the address segment records and the addresses, which requires two object classes. Figure 5 illustrates the attributes required to express the address segment (AddressSeg) and address (Address) information exchange needed under virtually all circumstances. Mandatory fields are shown in bold type; the primary key is underlined.

| AddressSeg |
|---|
| **AddressSegID** |
| **RoadSegID** |
| **RecordDate** |
| DirectionPrefix |
| TypePrefix |
| **StreetName** |
| TypeSuffix |
| DirectionSuffix |
| CompleteName |
| AlternativeStreetName |
| OddSide |
| **SideOfStreet** |
| **FromAddress** |
| **ToAddress** |
| JurisdictionCity |
| JurisdictionCounty |
| JurisdictionState |
| PostalCommunity |
| PostalState |
| PostalCode |
| Status |

| Address |
|---|
| **AddressID** |
| AddressSegID |
| **RecordDate** |
| **AddressNumber** |
| DirectionPrefix |
| TypePrefix |
| **StreetName** |
| TypeSuffix |
| DirectionSuffix |
| CompleteName |
| UnitType |
| UnitDesignation |
| SecondLine |
| PostalCommunity |
| PostalState |
| PostalCode |
| Status |

**Figure 6-Suggested information attributes for AddressSeg and Address classes.**

## AddressSeg Field Descriptions

**AddressSegID –** The unique identifier for the address segment. An address segment is a portion of a named street with a continuous range of address numbers and a single combination of street name, postal community name, state, and postal code. A new address segment is created when any one of these attributes changes. Hundred-number block ranges that reset incrementally at intersections often additionally define address segments. Separate address segments may describe left and right sides of a named street.

**RoadSegID –** The unique identifier for the roadway segment on which the address segment is located. Address segments cannot span multiple road segments, but multiple address segments may reference a single road segment.

**RecordDate –** The date the record was created.

**DirectionPrefix –** A cardinal direction used to differentiate one portion of a named street from another based on its displacement from a central address cross street. Domain is North, East, South, West, Northeast, Northwest, Southeast, and Southwest; or their one- and two-character equivalents.

**TypePrefix –** A means of differentiating one kind of road from another, used to make otherwise duplicative names unique. Appendix C of the U.S. Postal Service's *Publication 28: Postal Addressing Standard* defines the domain, which includes such values as ST, AVE, DR, LANE, CIR, BLVD, and LOOP.

**StreetName –** The primary street name element, such as "Main" or "23rd."

**TypeSuffix –** Same as TypePrefix, only coming after the primary street name component.

**DirectionSuffix –** Same as DirectionPrefix, only coming after the primary street name component.

**CompleteName –** The full text of the street name with all applicable prefixes and suffixes, such as "N Main St." Street names are typically decomposed in address databases into several constituent elements, expressed mainly as various prefixes and suffixes to the basic street name, as shown above. This field supports the transfer of a full street name as a single value.

**OddSide –** The side of the street, as determined by applying the direction of increasing address numbers, on which odd numbered addresses are located. Domain is Left, Right, Both, None, and Unknown. Used by some geocoding applications to properly place addresses along the address segment in lieu of using left- and right-side address ranges.

**SideOfStreet** – The side of a street to which this address-segment record applies. Domain is Left, Right, and Both. There is no implicit requirement that a matching odd-numbered side record balance an even-numbered side of the street record; both sides may contain odd- or even-numbered addresses.

**FromAddress** – The numerically lowest value in the continuous address range for this segment.

**ToAddress** – The numerically highest value in the continuous address range for this segment.

**JurisdictionCity** – The city with addressing jurisdiction for this address segment. Domain may be the official political unit's text name or the FIPS code value used to represent this entity.

**JurisdictionCounty** – The county with addressing jurisdiction for this address segment. The term 'county' includes parishes, townships, and similar terms, where applicable. Domain may be the official political unit's text name or the FIPS code value used to represent this entity.

**JurisdictionState** – The state with addressing jurisdiction for this address segment. Domain may be the official political unit's text name or the FIPS code value used to represent this entity.

*Note: It is anticipated that only one of the three* Jurisdiction___ *fields would be valid for any single address segment.*

**PostalCommunity** – The name assigned by the postal authority for the general location within which the address information must be unique. Postal community may differ from the name of the city with jurisdiction on this address segment.

**PostalState** – The name assigned by the postal authority for the state within which the address is located for delivery purposes. The term 'state' includes provinces and similar terms, where applicable. Domain is two-character state (in the U.S.) and province (in Canada) abbreviations.

**PostalCode** – The general address location identifier used by the postal agency. In the United States, this is known as the Zip Code, and consists of five mandatory numbers and an optional "Zip+4" extension consisting of a hyphen and four numbers.

**Status** – The status of the address segment record. Domain is Active, Proposed, Alternative, and Retired.

## Address Field Definitions

Fields in this class that are also in the AddressSeg class are not repeated as they have the same definition and domain.

**AddressID** – A unique identifier for an address record. An address, in the context of this model, is a physical address (a.k.a., delivery or situs address), as defined in the proposed NSDI *Address Data Content Standard*, available at http://www.fgdc.gov/standards/status/sub2_4.html.

**AddressNumber** – The portion of a street address that is not the street name, usually consisting of whole integer numbers with occasional fractional and alphabetic extensions. Address numbers generally identify an entire structure for the purposes of mail and package delivery.

**UnitType** – The type of mail delivery unit within a structure. Domain is Apartment, Suite, Unit, Office, Mail Station, and Building, plus their equivalent abbreviations.

**UnitDesignation** – The identifier for the delivery unit, such as a letter or number that is unique within the structure(s) reached through the combination of an address number and complete street name location. UnitDesignation may be used even when UnitType is [null] in order to convey address information; e.g., for duplexes identified with a letter suffix appended to the numeric address conveyed in AddressNumber.

**SecondLine** – An additional line for supplemental delivery address information, such as the floor on which an office is located.

As reflected in the mandatory fields, the address information transfer mechanism requires that RoadSeg features exist if AddressSeg records are conveyed, but that Address records alone may be transmitted. The proposed Road MAT data model provides the requisite street segments in RoadSeg features, from which TransitSegment features may be derived. Figure 6 illustrates this portion of the Transit MAT data model with the two proposed address classes. RoadSeg, RoadSubSeg, and TransitSegment are feature classes that may include geometry. A TransitSegment may be constructed from one or more RoadSubSeg features, each of which is part or all of a RoadSeg feature. A transportation agency may choose to represent the extent of a RoadSubSeg and/or an AddressSeg using a LinearAttributeEvent. Address classes extend the Road model but are required to meet Transit model application needs.

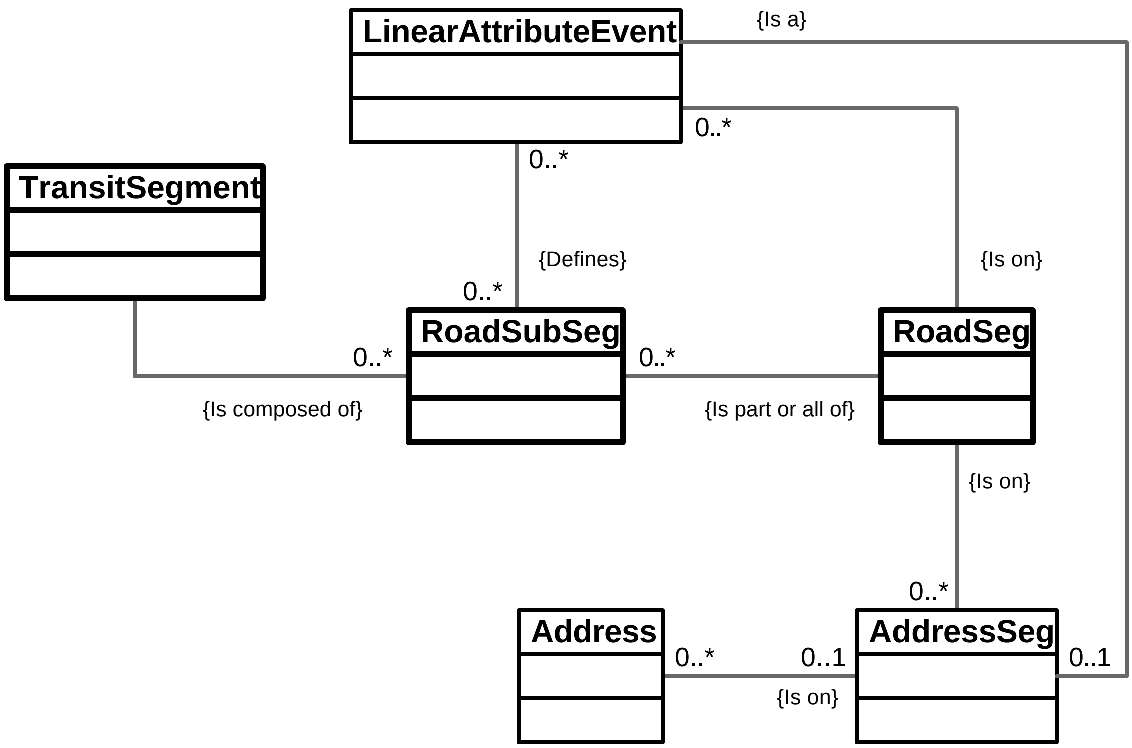


**Figure 7-Data model extension to support address information transmission.**

## Annex E. Linear Reference System

A considerable amount of information is located using linear locations. A linear location is specified as a distance along a one-dimensional feature, such as a roadway. The location is specified in one-dimensional coordinate, whose coordinate axis is the linear feature itself so that there is no need to resort to a two-dimensional Coordinate Referencing System.
Consider a location, A, along a linear feature, as shown in Figure 8.

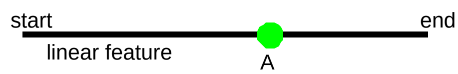


**Figure 8–Location along linear feature**

Instead of specifying the location of A in two-dimensional space, as is typically done with a GIS, the location of A can be specified relative to the linear feature. Figure 9 shows the specification of the location of A as an absolute distance from the start of the linear feature, measured in the direction of the linear feature (from its start toward its end).

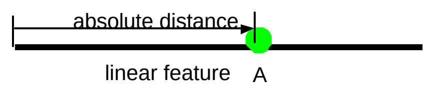


**Figure 9–Absolute distance to a location along a linear feature**

Predefined, intermediate locations may be known, if the linear feature is sufficiently long. An example is the reference posts along interstate highways. If the location of these referents is known (as their absolute distance from the start of the linear feature), locations can be specified as a relative distance from the referent, as shown in Figure 10.

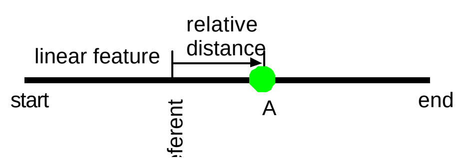


**Figure 10–Relative distances from a referent to a location along a linear feature**

It is also possible to specify a location that is beside, but not on, a linear feature, using linear referencing. Figure 11, demonstrates the use of lateral offsets to move perpendicular to a location from the centerline of a linear feature. By convention, offsets to the left are negative and those to the right are positive, when looking in the direction of the linear feature. To arrive at location B, travel along the linear features the absolute distance from its start (or relative distance from some referent), and then turn left or right and travel perpendicular to the linear element a distance equal to the offset value.

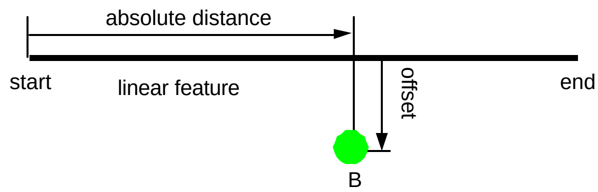


**Figure 11–Absolute distances along a linear feature and then lateral offset to the side**

It is also possible to specify offsets as being relative to some offset referent, such as the back of a curb, or the edge of a shoulder. Location C, shown in figure 12, is depicted at an offset from an offset referent whose offset from the centerline of the linear feature is known.

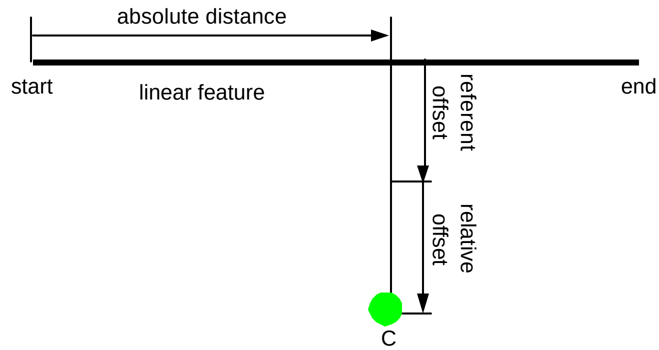


**Figure 12–Absolute distances along a linear feature and then lateral offset to the side relative to an offset referent**

Figure 13 shows the UML of the LRS proposed for this standard. Linear referencing occurs on a RoadSeg. The XOR sign, at the association of RoadSeg to Referent, indicates that a Referent instance is either Offset Referent or just a Referent but not both.

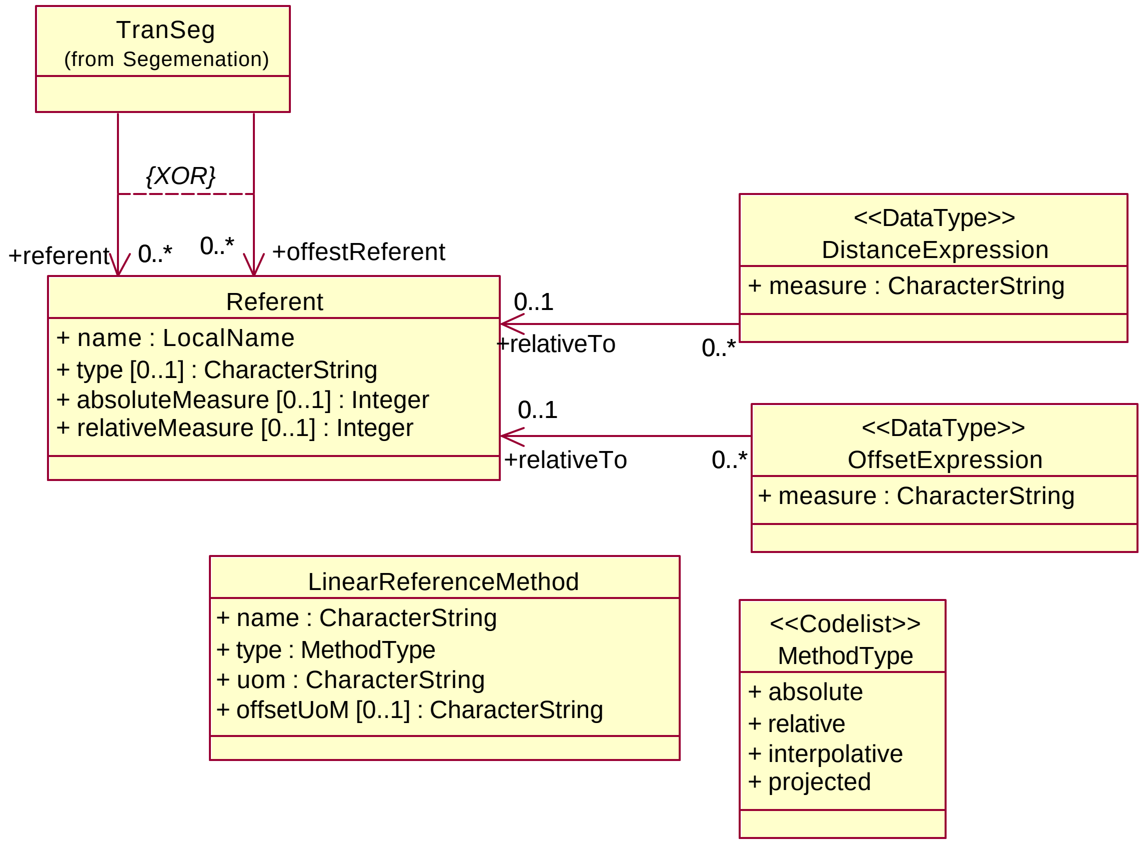


**Figure 13–Linear Reference System model**

## LinearReferenceMethod

## Semantics

The method used to measure a location along or beside a linear feature as a distance along (and optionally laterally offset from) the linear feature. Numerous schemes have been devised for measuring relative and absolute distances along linear features. These are commonly referred to as Linear Reference Methods. Four Linear Reference Methods are defined as follows:

– *Absolute*: The location is measured along the linear element starting at the beginning of the linear element;
– *Relative*: The location is measured along the linear element starting at the location of a predefined referent;
– *Interpolative*: The location along the linear element is determined by applying linear interpolation of the specified measure against the total length of the linear element;
– *Projected*: The location along the linear element is determined by projecting the specified spatial location onto the linear element.

### Distance expression

#### Semantics

The linear distance measured along the linear element.

### Offset Expression

#### Semantics

The lateral offset distance measured perpendicular from the linear element.

### Referent

#### Semantics

A named location along a linear element whose distance along the linear element measured from the start of the linear element is known or determinate.

## Attributes for Linear Reference System

Listed below in table 4 is the linear referencing system and its attributes. The ‘definition’ column gives a brief definition of the term. The ‘M’ and ‘O’ in the ‘Obligation/Condition’ column stand for ‘Mandatory’ and ‘Optional’. The ‘Maximum Occurrence’ column indicates whether there are one or more occurrences. ‘Data type’ shows how the object is encoded. The ‘Domain’ column shows the object type.

**Table 14–Linear Reference System**

| | Name / Role name | Definition | Obligation / Condition | Maximum occurrence | Data type | Domain |
|---|---|---|---|---|---|---|
| 1. | LinearReferenceMethod | method used to measure a location along or beside a linear feature as a distance along (and optionally laterally offset from) the linear feature | Use obligation from referencing object | Use maximum occurrence from referencing object | Class | |
| 2. | name | name used to identify the linear reference method | M | 1 | CharacterString | Free Text |
| 3. | type | type of measurement method | M | 1 | Class | MethodType |
| 4. | uom | the units of measure of the measured value along the linear element | M | 1 | CharacterString | “miles,” “kilometers,” “feet,” “meters,” “percent,” “degrees” |
| 5. | offsetUoM | units of measure of the lateral offset | C / if LocationExpression.offsetExpre | 1 | CharacterString | “feet,” “meters” |
| 6. | DistanceExpression | linear distance measured along the linear element | Use obligation from referencing object | Use maximum occurrence from referencing object | Class | |
| 7. | measure | for an absolute LRM, the absolute distance measured along and from the start of the linear element in the direction of the linear element;<br>for a relative LRM, the relative distance measured along the linear element but from a referent on the linear element;<br>for an interpolative LRM, the interpolated distance between the start and end of the linear element;<br>for a projected LRM, the coordinate values of the location being projected onto the linear element | M | 1 | CharacterString | Free Text |

| | Name / Role name | Definition | Obligation / Condition | Maximum occurrence | Data type | Domain |
|---|---|---|---|---|---|---|
| 8. | *Role Name:* referentName | name of the referent on the linear element from which the relative distance is measured | O | 1 | Association | Referent |
| 9. | OffsetExpression | lateral offset distance measured perpendicular from the linear element | Use obligation from referencing object | Use maximum occurrence from referencing object | Class | |
| 10. | Role Name: offsetReferent | name of the offset referent left or right of the linear element from which the relative distance is measured | O | 1 | Association | Referent |
| 11. | Referent | named location along a linear element whose distance along the linear element measured from the start of the linear element is known or determinate | Use obligation from referencing object | Use maximum occurrence from referencing object | Class | |
| 12. | name | name of the referent | M | 1 | CharacterString | Free Text |
| 13. | type | type of referent | O | 1 | CharacterString | Free Text |
| 14. | absoluteMeasure | absolute distance measured along and in the direction of the linear element from the start of the linear element to the referent | O | 1 | Integer | Integer |
| 15. | relativeMeasure | relative distance measured along and in the direction of the linear element from the previous referent | O | 1 | Integer | Integer |
| | OffsetExpression | lateral offset distance measured perpendicular from the linear element | Use obligation from referencing object | Use maximum occurrence from referencing object | Class | |
| 16. | Role Name: offsetReferent | name of the offset referent left or right of the linear element from which the relative distance is measured | O | 1 | Association | Referent |
| 17. | Referent | named location along a linear element whose distance along the linear element measured from the start of the linear element is known or determinate | Use obligation from referencing object | Use maximum occurrence from referencing object | Class | |
| 18. | name | name of the referent | M | 1 | CharacterString | Free Text |
| 19. | type | type of referent | O | 1 | CharacterString | Free Text |
| 20. | absoluteMeasure | absolute distance measured along and in the direction of the linear element from the start of the linear element to the referent | O | 1 | Integer | Integer |

| | Name / Role name | Definition | Obligation / Condition | Maximum occurrence | Data type | Domain |
|---|---|---|---|---|---|---|
| 21. | relativeMeasure | relative distance measured along and in the direction of the linear element from the previous referent | O | 1 | Integer | Integer |

## Diagram: Nested Relationship of NSDI Framework Data Content Standard Harmonization